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An efficient trajectory based routing scheme for delay-sensitive data in wireless sensor network☆

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A B S T R A C T

Exploiting sink mobility for balancing the energy dissipation of sensor nodes and preventing energy holes is a growing trend in the field of wireless sensor network (WSN). The mobile sink moves throughout the network and collects data in a single-hop fashion resulting in less energy consumption of the sensor nodes. Despite the advantage of this scheme, data forwarding to the mobile sink during an emergency situation is a major issue that should be dealt with. For efficient data delivery within the stipulated deadline, the sensor node which has sensed a delay-intolerant data needs to forward the data towards the mobile sink. In this paper, a Moore curve based trajectory of the mobile sink has been considered for efficient sink based data collection. This work is also motivated by anycast forwarding of delay sensitive data to the mobile sink before the sensed data lose its relevance, where the node follows a strict sleep-wake pattern. We have evaluated the effectiveness of the proposed trajectory based data collection scheme by simulation using MATLAB. The delay-intolerant data routing scheme (DRS) shows that the data reaches the mobile sink within the given deadline while restricting the energy dissipation of the sensor nodes to a minimum. This have been verified by extensive simulations which show that when compared to static sink, the usage of a mobile sink improves the network lifetime by almost 12%. This work has also been compared with an existing work (PMDD) to show its validity. The simulation results depict that DRS shows an improvement of about 25%–29% in terms of network lifetime.

1. Introduction

Wireless Sensor Networks have been used in a variety of applications during the last couple of decades, some of which include military, agriculture, environment monitoring, home automation, smart transportation etc [1]. In most applications of WSN, the sensor nodes are battery-operated devices which cooperatively collect data from the environment and forward this data to the sink or base station for further processing. These tasks lead to the energy consumption of the batteries. Given the deployed environment, the batteries may be difficult to replace or recharge. These difficulties have paved the way to extensive research in designing energy-efficient protocols.

In a typical environment, the sensor nodes exhibit many-to-one communication with the sink, resulting in faster energy depletion of the sensor nodes near the vicinity of the sink which is famously known as the energy-hole problem or the

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Hot-Spot problem [2]. The introduction of sink mobility assists in balancing the energy dissipation of the sensor nodes [1]. In [3], the authors used a mobile collector to collect data from a disconnected network. Additionally, several application environments require sink mobility in the sensor field, e.g., in a disaster management system, a rescuer equipped with a PDA (Personal Digital Assistant) can keep a lookout for survivors in a disaster area.

As required in most of the practical applications, data should be timely delivered to a sink after a sensor node has sensed the data. In this work, when the mobile sink comes to a node's vicinity, the delay-tolerant data is directly forwarded to the mobile sink in a single-hop fashion. But the delay-intolerant data are forwarded to a suitable node in the path of a mobile sink so that the data can reach the mobile sink before the stipulated deadline. For example, the events of fire break-out and intruder detection in the surveillance applications should be notified within a predefined time [4]. In order to improve network lifetime sensor nodes can be put to sleep when there is no need to relay or transmit packets by them. Such sleep-wake scheduling policy reduces energy consumption to a great extent. But this may increase the delay for multi-hop communication as a sensor node has to wait for its relaying sensor node to wake up for data forwarding leading to failure of deadline. This paper focuses on improving this delay while taking the energy-constraint into account. This is achieved through anycast forwarding policy [5]. In anycast forwarding scheme, instead of forwarding the packet to a designated next-hop sensor node, multiple candidates of next-hop sensor nodes are maintained. Thus, the main contributions of this work are summarised as follows:

1. We propose a trajectory for the mobile sink based on Moore Curve.
2. We also propose a data forwarding scheme for the sensor nodes to route their delay-sensitive data based on their sleep-wake scheduling policy.
3. We analyse the complexity of the data routing policy.
4. To show the effectiveness of our proposed algorithm, extensive simulations are carried out to prove that the algorithm with a mobile sink performs much better when compared with static sink and with similar algorithms.

The rest of the paper is organised as follows: Section 2 describes the related work pertaining to the works done in this area. Section 3 presents the trajectory design based on Moore Curve and discusses the proposed method of data-forwarding scheme in detail. The simulation results and the corresponding discussions are given in Section 4 . Finally Section 5 concludes the paper.

2. Related study

Several works based on sink mobility and data dissemination have been proposed in the literature. Some of them are discussed next.

2.1. Sink mobility

In [6], the authors have provided an extensive survey of the related literature based on mobile elements. Based on movement of sink, mobility patterns can be classified as: (i) Random mobility, (ii) Controlled mobility and (iii) Predictable mobility. These mobility patterns indicate the variety of data collection protocols. In random mobility animals may be used as in [7] to collect data in wild surroundings. In such a scheme it is very difficult to predict the movement of the nodes. In controlled sink mobility, the movement of a sink is controlled in accordance with the network dynamics. Controlled mobility is used in [8] for mobile sink movement. The paper proposes a Mobile Sink based adaptive Immune Energy-Efficient clustering Protocol (MSIEEP) to alleviate the energy holes. MSIEEP uses the Adaptive Immune Algorithm (AIA) to find the optimal number of clusters in the network. In predictable mobility the sensors can predict the path that a sink will take. For data dissemination to the mobile sinks predictable mobility can be exploited. This work uses predictable mobility for mobile sink trajectory and thus some works on predictable mobility are discussed next.

Predictable mobility is used in [9] where the sensor nodes know the path of the mobile sink and to save energy go into sleep state until the predicted time for data transfer. In [10] Ying et al. proposed prediction model based on a novel cluster-based prediction strategy which evaluates the next location of a mobile user based on the frequent behaviours of similar users in the same cluster determined by analysing the users common behaviour in semantic trajectories. A statistical approach for prediction of mobility is used in [11]. A wheeled vehicle model and a stochastic response surface method have been proposed for this approach. The wheeled vehicle model is used to calculate the interaction forces within the environment whereas the other method is used for uncertainty propagation using the determination of a statistically equivalent reduced model. The authors in [12] use the knowledge of the behaviour of mobile sinks to determine a routing scheme to minimise the energy consumption and congestion in the network. Next, some data dissemination protocols are discussed.

2.2. Data dissemination

Abdul et al. [13] propose a Virtual grid-based Dynamic Routes Adjustment (VGDRA) scheme that minimises the routes reconstruction cost of the sensor nodes when the sink has shifted its position while maintaining nearly optimal routes to the latest location of the mobile sink. A set of communication rules are formulated to dictate the routes reconstruction process which requires only a limited number of nodes to readjust their data delivery routes toward the mobile sink.